LCAC: THE INHERITOR OF BRITISH HOVERCRAFT TECHNOLOGY

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Fig 1: LCAC-5 Off the Beach at ACU5

Abstract

This article will describe LCAC progress to date and give an overview of some of the design and development problems that are specific to this type of hovercraft and how they have been tackled. A special review of the skirt design is then given in the light of events since their service began.

Build Programme

The LCAC or the US Navy Landing Craft, Air Cushion now represents the largest accumulation of hovercraft anywhere in the world. Contracts for new vessels now total 91 craft and about 60 have already been delivered to the Navy.
There are two manufacturers of the vessels, Textron Marine Systems (TMS) at New Orleans and Avondale Gulfport Marine (AGM) at Gulfport, Mississippi. TMS have had contracts for 76 craft and AGM have 15, the last one recently delivered. The large number of craft on order has enabled the builders to plan efficient production lines using a high degree of automation.

Two purpose-built LCAC bases have been constructed, one on the West Coast (ACU5) at Camp Pendleton, California near San Diego and one on the East Coast (ACU4) at Little Creek near Norfolk, Virginia. Approximately 30 craft are currently at each base when not deployed elsewhere in the world.

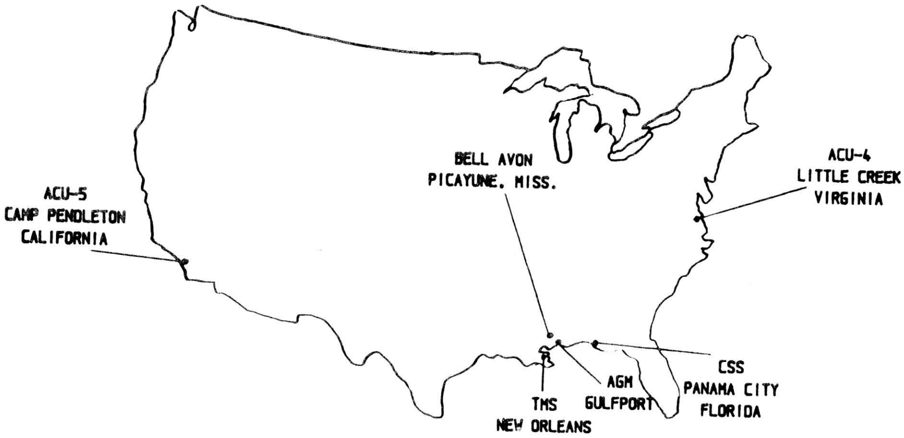

Fig 2: Location of LCAC Sites

Each base comprises a large parking area for 45 craft and a ramp extending to the sea several hundred yards long. Both the ramp and the manoeuvring apron are made of a particularly abrasive concrete. At the base are extensive workshops for maintenance of all the craft systems, hangers for three craft and accommodation for crews. Skirt maintenance and mobility of disabled craft is facilitated by a Travelift mobile gantry which can also collect craft from the sea. Up to 50% of operation of the craft is over this concrete surface.

History

The origin of the LCAC can be derived from U.S. studies from the early 1960's which state the limitation of conventional landing craft, which it was estimated could be used over only 17% of the world's coastline. Even then, troop landings on beaches involved wading through seawater carrying heavy equipment with the possible risk of enemy fire. It was not until the seventies that the Advanced Amphibian Landing Craft programme developed to a stage where test craft were built.
According to the US military methods, contracts were placed with two companies to design and build a craft to the same requirements. Critical specifications were defined for maximum dimensions and minimum performance. The length and width limits were defined by the need to fit into the well deck of existing Assault Ships or Mother Ships and a payload of 60 tons was chosen which was the weight of a main battle tank. There are several classes of ship with floodable well decks originally designed for conventional landing craft. The earlier types are known as LSD-36 and LSD-41 and the more recent ships are LHD class. The contracts were awarded to Bell Aerospace and Aerojet General who built craft called the JEFF-B and the JEFF-A respectively.

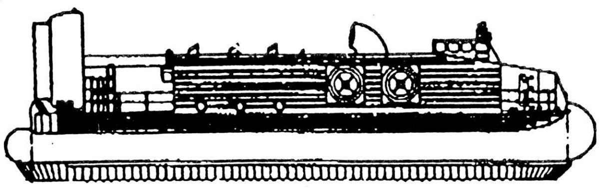

Figure 3. JEFF-B Prototype

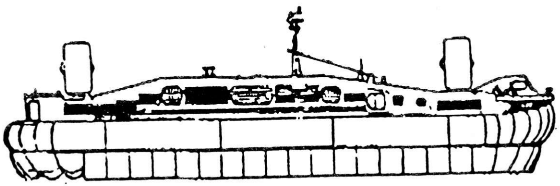

Figure 4. JEFF-A Prototype

Despite the strict constraints of the specification the craft were very different. JEFF-A had four rotating shrouded propellers whereas the JEFF-B had two fixed shrouded propellers and bow thrusters. Another difference was in the skirt design. The JEFF-B had a British Hovercraft Corporation (BHC) design of bag and finger skirt, while the JEFF-A had a peripheral cone skirt. The difference in principle used for the skirt design will be discussed later.
The two craft were delivered in 1978 and 1979 respectively and both were subjected to a two year series of tests by the Navy and its Contractors which resulted in an impressive batch of reports. Every conceivable aspect of the design was studied in theory and practice. In one test, JEFF-A was subjected to an underwater explosion to assess the vulnerability of air cushion craft to mines. Although the explosion in this case was not directly below the craft, the damage that occurred was believed to have been slight in comparison to a similar sized ship and the craft itself survived to see service in oil exploration in Alaska.

Fig 5: LCAC-5 being hoisted by a Travelift

Bell Aerospace had previously manufactured another series of landing craft type vessels for Canada and the US Army known as Voyageur and later the Viking, derived from BHC technology. The LACV-30 was a 30-ton payload craft using essentially SRN6 designs for lift air, propulsion and skirt details built for the US Army. In all 26 of these craft were bought, although it has recently been decided to take them out of service.

Subsequently, Bell Aerospace Textron (now Textron Marine Systems) was awarded the contract to design and build the production version of the landing craft, to be known as LCAC.

LCAC Configuration

The LCAC was intended to combine the best characteristics of the JEFF craft and so reduce costs and risk. The craft is, not surprisingly, most similar to JEFF-B but has the following major differences:

1. Four uprated TF40B gas turbines were used instead of six.

2. No attempt was made to incorporate the structural strength of the superstructure on to the basic raft.

3. Longitudinal fan shafts were used instead of transverse shafts so eliminating six gearboxes per craft.

4. Composite propeller blades with erosion strips were used in place of the aluminium ones on JEFF-B.

The structure of the LCAC is welded marine grade aluminium type 5456. This type of construction lends itself to automated welding and 70% of welds are performed by machine. Much use is made of special alloy extrusions and forgings to reduce machining effort. The benefits to a military vessel of using welded aluminium, as opposed to GRP or high tensile alloy, are fabricating cost and reparability. It was necessary to carefully estimate the effect of vibration on those parts of the hull that are stressed cyclically by the rotating machinery to avoid fatigue problems. The inspection and maintenance procedures carried out at the ACU bases provide a fall-back to this.

The design of the skirt was again subcontracted to B.H.C. who used their well-developed pressurised bag and finger design with a short keel and transverse cushion dividers to separate the cushion into three areas.

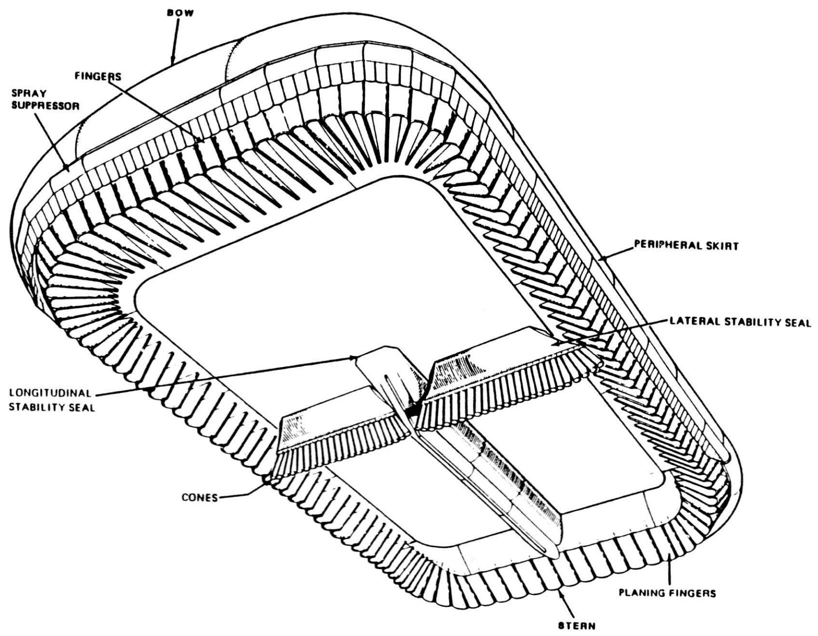

Figure 6: Underside of skirt

Two aspect of the skirt design originated with the JEFF craft and were incorporated. The stern cones were of a wide trailing type with stiff planers on the forward face instead of the narrow upright cones that feature on BHC's other skirts. These cones are attached to an outer bag continuous with the side skirt. The spray suppressor is of a complex inflated design that has a small extra tube fed by air through the main outer bag that runs horizontally around the bow and sides of this skirt just above the finger attachment. Small chip bag shaped cones are then attached under this tube and are inflated through it.

Figure 7: Production Line at TMS

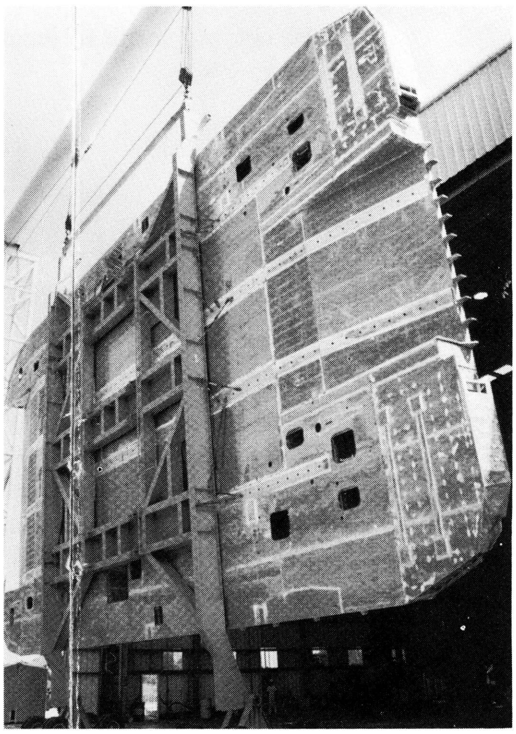

Figure 8: The hull being inverted

The hull is basically a flat raft initially made upside down and inverted for completion. Some sections of the raft are sealed for use as fuel tanks. The superstructure comprises a series of modules which are bolted into position and do not contribute to the overall strength of the structure but are of course fitted with defined tolerances relative to each other.

The craft incorporates numerous systems which are never seen on commercial hovercraft. Some relate to the high degree of redundancy incorporated, so that the craft can operate with major structural and machinery damage.

A 27ft wide ramp is fitted at the bow and a narrower one at the stern which allows rapid loading and offloading of payloads and vehicles. Since the skirt attachments cross the ramps, hinge pockets are provided at the four corners to allow the skirt to fold out when the ramp opens. The craft are only lightly armed with two machine guns as standard.

The structural design of the craft and the fact that the aluminium is unpainted gives a very functional, some say ugly, appearance, and distinctly different to the sleek design of most high speed commercial vessels. However the close affinity of the operational and service crews to the craft at the ACU bases have inevitably lead them to appreciate their operational capabilities and their ease of maintenance.

Normal crew is 5 men seated in a comparatively small command module on the starboard side. On the port side are seats for a further 24 troops in another module. The driver is known as a "Craftmaster".

Length on cushion	88 ft
Beam on cushion	47 ft
Height on cushion	23 ft 6 in
Skirt height	5 ft
Deck area 1809 sq. ft	
Light ship weight	94 tons
Design combat weight	105 tons
Design payload	60 tons
Performance with design payload:	
Calm water 50 knots	
Sea state 2 40 knots	
Sea state 3 30 knots	
Enqines	
4 TF-40B Gas Turbines	4200 h.p. each
2 T-62 APUs	150 h.p. each

Table 1: LCAC Main Characteristics

The Skirt

Both the JEFF craft had an assortment of skirt problems during their careers. There was naturally a great concern for the LCAC to use the system which would give maximum serviceability for a reasonable cost in the long term.

The principle of the skirts was quite different in that the JEFF-A had 62 cones that could be pressurised higher than cushion pressure so providing roll and pitch stiffness, whereas the JEFF-B had about twice the number of fingers and, as mentioned before, the dreaded cushion dividers. I say dreaded because these items, although undoubtedly effective in increasing roll stiffness and improving stability in damage conditions, add weight and give rise to difficulties in maintenance and inspection.

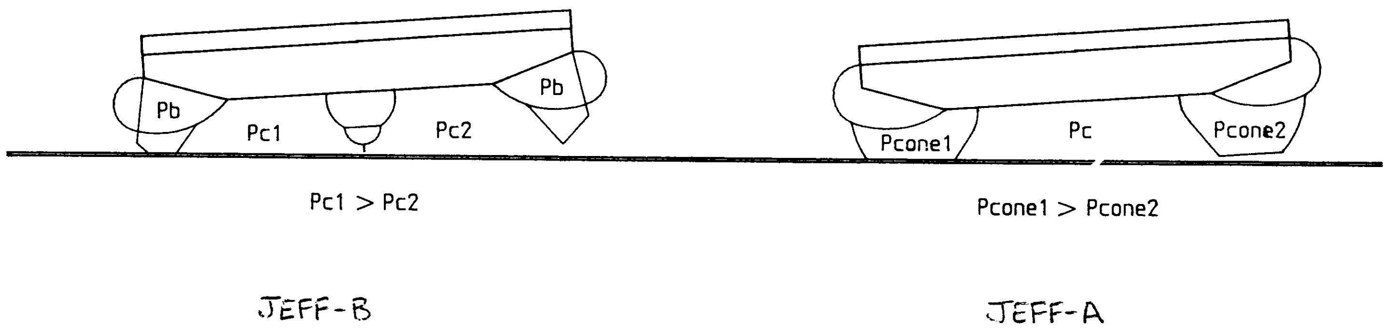

Fig. 9 Comparison of methods of achieving stability

However the bag and finger design was found to be more reliable and less prone to strange dynamic effects, probably because the concept had been more thoroughly developed by British Hovercraft Corporation over the years. The main antecedents for the JEFF-A concept were pericell or "jupe" skirts from Bertin in France, which although having almost as long a history behind them, had not got the hard experience of commercial operations. The JEFF-A suffered from numerous problems that a draftsman would have difficulty to anticipate. The cones distorted in a way such that the skirt was wider than the Mother Ship's well deck when hovering. Several fastening problems immediately revealed themselves, which given time might have been resolved.

An aspect of fingered skirts that was probably not fully appreciated during the JEFF-B trials was the way in which fingers remain functional even when badly damaged. Of course performance and cushion height is eventually lost, but only after the fingers are severely torn or eroded. This is not the case with pericells. The choice of fingers has meant that although skirt wear and damage was found early on with LCAC operations, it has never been a strategically important deficiency. Although representing a high proportion of total maintenance costs, the skirt rarely appears in the top ten Reliability and Maintenance issues.

The stern skirt design was particularly difficult. The rationale followed in the choice of planing cones goes like this:

a) It would be nice to use fingers at the stern but they scoop water.

b) To prevent scooping, a forward face needs to be incorporated to make them into cones.

c) Cones are more rigid than fingers and do not like being buckled. They also need a precise size of hole at the bottom so that any water drains out but an adequate internal pressure is maintained to keep their shape.

d) Cones abrade and wear so enlarging the holes. They then lose their shape and their ability to retain cushion air.

e) The part that abrades should be made thick and the part that buckles can remain thin.

The LCAC cones are angled aft so that the abrasive wear is taken on a thickened planer forming the forward face, and the buckling occurs in the thinner *aft* part. Only the transverse stability skirt uses open tipped upright cones.

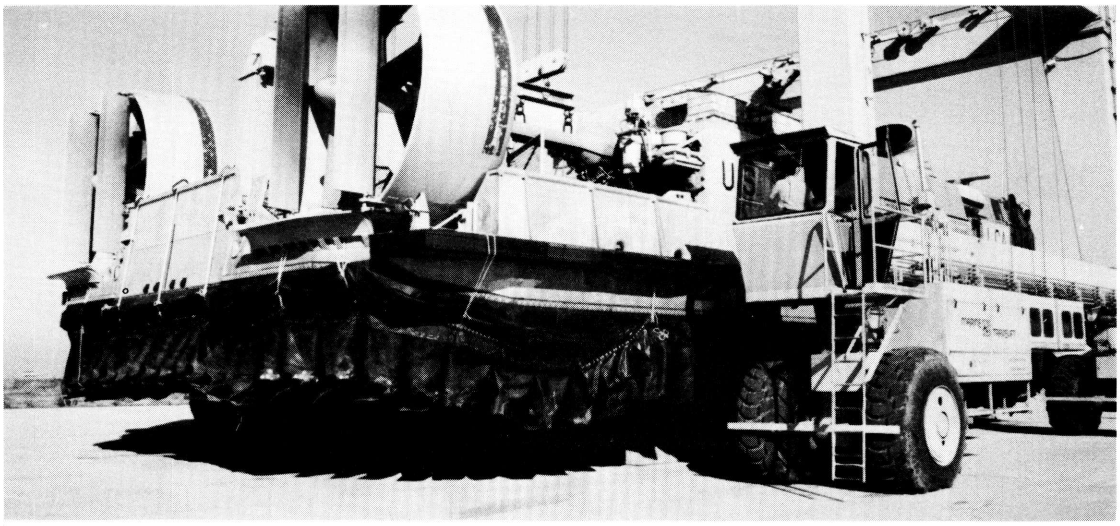

Fig 10. Stern of LCAC showing the stern cones

An attempt to slow the wear on these planers has been made using hardened steel washers bolted around the lower parts. This idea obviously moves a long way from the concept of hovercraft being separated from the ground by a layer of air. The cone planers are made from four plies of skirt material and because of the amount of time spent hovering over concrete at the ACU bases wear through the layers one by one. The problem is exacerbated by the desire of drivers of varying experience using skirt drag to stabilise the craft in yaw as they negotiate the long slope down to the sea, often with a cross wind.

The spray suppressor design was one of several types tested on the JEFF craft. The idea is quite simple: to deflect spray generated at the finger tips so that it does not impede the driver's vision. In trials the simpler designs such a weighted sheet or bristles attached to the apron proved either ineffective or hazardous, and the very complex system used today was chosen. Because of its position on the skirt it is subject to much of the same buckling and abrasion that the main skirt suffers and so repair effort has been heavy.

The bow and side fingers suffer from scuffing on the concrete which leads to wear such as in Figure 11. On the side fingers the abrasion occurs where the material knuckles eventually causing a diagonal slot to appear. These slots join up leaving a shredded appearance. Little of the flagellation damage normally seen on commercial hovercraft is apparent. Attempts to simulate this wear in laboratory tests have indicated that increasing the coating thickness is counterproductive because of the harder creases formed by thicker materials. The fingers are made of nylon coated with a blend of mainly natural rubber. Any other type of material has proven to be inferior in this abrasion characteristic.

The total skirt design is enshrined in 205 drawing sheets and the assembled skirt contribute about 5 tons to the weight of each craft.

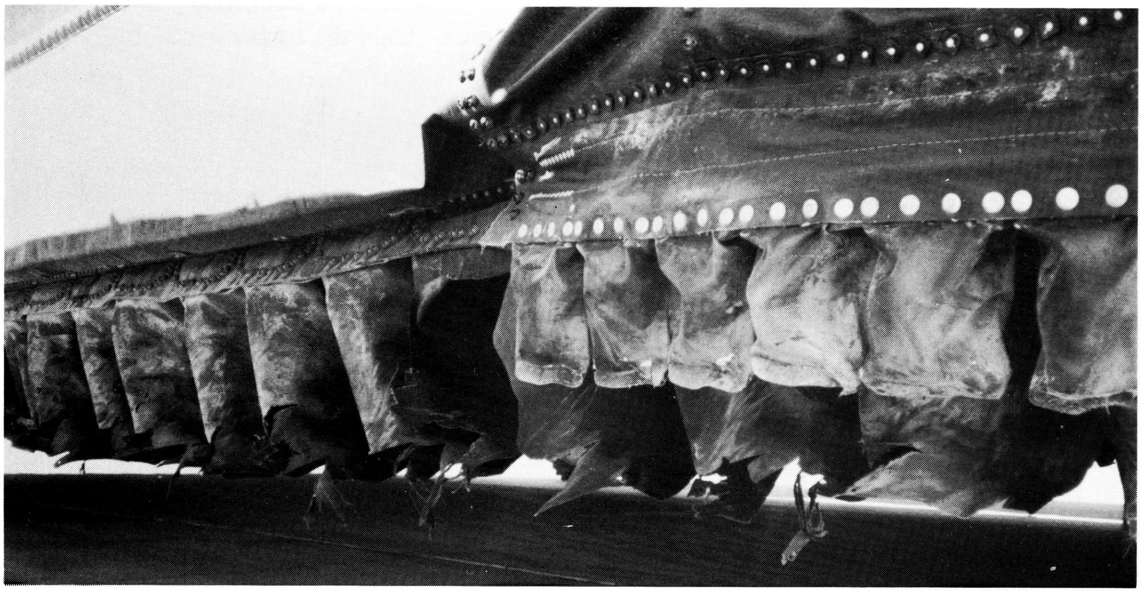

Figure 11: Side Skirt showing worn fingers and part of spray skirt

Teething Problems

The first production LCAC craft was delivered in 1984 and in almost all respects met its operational requirements.

Some technical problems were found however and the delivery of the second and subsequent craft was delayed until they had been resolved by a joint contractor and Navy team. The problems included a complex torsional oscillation in the drive train, gearbox bearing failure, propeller delamination and engine air fan failure. These are detailed more fully in Ref 3. A more typically hovercraft problem was the system for rotating the bow thrusters. On LCAC-1 the glass- fibre nozzles had a tendency to become jammed due to contamination with dirt and alignment inaccuracies. The solution required an extensive redesign effort and it proved the longest running problem of those identified on the first craft.

One change found necessary which is visible on later craft is the propeller duct guarding. Accidents occurred during early trials with damage to the propellers from both forward and aft. This is partly as a result of the need to set the propellers quite low to limit the height of the craft to 23 ft 6 in. Green water from surf was found to hit the propeller in some circumstances, and foreign objects were able to sucked in to the inlet, both causing failure. A wave deflector fence was fitted at the stern and sides near the shroud. All craft are now additionally fitted with a conical metal screen looking like a spider's web in front of each duct which reduces the risk of foreign object damage and risk to personnel. It has been acknowledged that these protection devices only partly reduce the risk of propeller damage and the main security is still driver technique to avoid wave damage, and the avoidance of loose items on the deck.

Trials

Each craft delivered has now three stages of acceptance trials, all supervised by Navy departments. The first are the Builders Trials and the second are the Navy Surveyor's Acceptance Trials conducted at or near the manufacturer's site. The craft are then delivered, initially to CSS Panama City, and then to either ACV base. There is then a Final Contract Trial at 6-8 months after delivery when the craft is officially presented to the Navy.

Into Service

Some well publicised military exercises have used LCACs. Fourteen LCACs were sent to the Gulf during the Iraqi War. They were widely seen during exercises on the Saudi Arabian coast and may have been used to convey the impression that an assault was to be made to an Iraqi beach. In the event all troops were landed through Saudi ports and transported overland.

The craft have been called to do a wide variety of jobs since they have been in service, partly it seems to investigate the possibilities available with the new string to the Navy's bow. Operations have been carried out to land troops on such diverse shore lines as Norway, Saudi and the Caribbean. Some craft have been used in drug interdiction service in the Caribbean and Gulf areas, and have seized huge quantities of drugs. In these operations the craft have been found to complement the inflatable boats effectively.

In Somalia the craft have transported thousands of tons of grain, vehicles and troops of various nationalities to support the UN relief operation. The use of hovercraft in this type of terrain where roads and ports are poorly provided has been clearly demonstrated.

Special Adaptions

The LCAC has proved itself suitable for a variety of different roles with minor modifications. Trials of some of these has lead to the development of modification kits which can be held on the Mother Ship and fitted by the accompanying crews.

1. Cold Weather Arctic Kits

Arctic kits are adaptions which enable the craft to be used in temperatures down to -30°F (-34°C). These kits involve no change to the standard skirt which it has been found is mostly limited to operations over prepared ice tracks and is unable to traverse large ridges. It has been envisaged that LCACs would service temporary bases in the Arctic or could carry equipment for anti-submarine warfare.

2. Mine Countermeasures

The LCAC has proven suitable for conducting mine sweeping operations towing an array behind it similar to systems currently specified for helicopters. The ACV has several advantages over the helicopter such as weather conditions, range and endurance.

The LCAC is obviously suitable for mine laying with its high speed and deck space.

3. Missile Carrier

The LCAC has been considered a suitable launch platform for Intercontinental Ballistic Missiles of a type that is also carried by truck or rail wagon. A wide variety of Anti-Aircraft, Anti-Submarine and Surface Warfare systems have been considered for use on the craft and many possibilities are open. The craft have few limitations compared to a ship, but care has to be taken to prevent debris such spent shells from impacting the propellers.

4. People Carrier

The requirement for evacuation of large numbers of civilians is a senario that may well become required in the world's trouble spots. A folding cover for the deck is available as a kit to convert craft for this purpose.

For many of the corners of the world where access was difficult the question of how to land a force has been answered, leaving the main question being where? As contributors to the LCAC program we cannot now expect to be consulted as to where the Americans choose to deploy them and certainly the craft will feature in most assaults that are planned by the "World's only Superpower". We should expect that some other countries of the world will recognise the extra power that a fast, fully amphibious landing craft gives to their Navies and will develop similar craft, directly or indirectly using British technology.

Figure 11: LCAC Entering the Mother Ship

References

1. LCAC: A revolution at Sea UH Rowley and L. W. Hale, Intersociety Advanced Marine Vehicles Conference, June 1989.

2. The Technology Matures: J. J. Halisky and R. G. Moore ditto.

3. Hovercraft Development D. R. Lavis, Intersociety High Performance Marine Vehicle Conference, June 1992.

4. LCAC: A Systems Evolution. J. Auzins and U. H. Rowley, ditto.

5. The LCAC in Tests and Trials, D. F. Bobeck, ditto.

6. On Cushion: LCAC Bulletin, June 1993. Dept. of the Navy.